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RESEARCH AND DEVELOPMENT OF ABRASION RESISTANT TREATMENTS FOR DACRON WEBBINGS

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MATERIALS LABORATORY
CONTRACT NUMBER AF 33(616)-2563
PROJECT NUMBER 7320

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Carpenter Litho & Prtg. Co., Springfield, O.
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FOREWORD

This report was prepared by the Fabric Research Laboratories, Inc., Dedham, Massachusetts, under USAF Contract No. AF 33(616)-2563. This Contract was initiated under Project No. 7320 "Air Force Textiles Materials," Task No. 73201, "Textile Materials for Parachutes," formerly RDO No. 612-12," "Textiles for High Speed Parachutes," and was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with 1st Lt. R. A. Sublette acting as project engineer.

Gratitude is expressed to the B. F. Goodrich Chemical Company, Rohm and Haas Company, Shawinigan Resins Corporation, Rubber Corporation of America, General Electric Company, and Dow Chemical Company for advice and supplying samples of resin dispersion. Materials for the optimum finish applied to 250 yards of Dacron webbing were contributed by the Dow Chemical Company.

The finishes tested were not developed or intended by the manufacturer for the conditions to which they have been subjected. Any poor performance of a finish under these tests conditions is not indicative of the utility of the finish under less stringent conditions or for other applications.

Dacron is a registered trade name belonging to the E. I. duPont deNemours and Co., Inc.

This report covers period of work from June 1954 to August 1955.

ABSTRACT

The purpose of the work herein reported was the development of finishes which could be applied to Dacron webbing with resulting increase in abrasion resistance. The finish was to remain flexible at -65°F. and be stable to artificial sunlight for 100 hours and to a temperature of 350°F. for 16 hours.

A satisfactory method for determining flexibility of webbings at standard conditions and at -65°F. has been developed.

Preference was given to commercially available water dispersions of a number of different types of resins such as acrylic, acrylonitrile, natural rubber and silicones because of their freedom from hazards of toxicity and flammability and their ease of handling.

Webbings treated with one particular silicone and catalyst emulsion were superior to all other treated samples from the point of view of abrasion resistance, low temperature flexibility and resistance to heat ageing. However, the resistance to artificial sunlight for 100 hours was lowered so that the webbing retained only 60 to 70% of the strength of a similarly exposed untreated sample, whereas a 90% retention was specified. In spite of this, the other aforementioned properties were so superior that it was decided to commercially apply this silicone treatment to 250 yards of Dacron webbing.

PUBLICATION REVIEW

This report has been reviewed and is approved

FOR THE COMMANDER:

R. W. CONNERS
Lt Colonel, USAF
Assistant Chief
Materials Laboratory
Directorate of Research

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I. INTRODUCTION:

The prime objective of this research was the application and evaluation of resin finishes which could be applied to Dacron webbing to increase its resistance to abrasion. This Dacron webbing was a heat stable type, 1 3/4" wide and 8700 lbs. breaking strength as described in Wright Air Development Center Technical Report 55-135. It is a counterpart of nylon webbing manufactured according to Specification MIL-W-4088B. In addition to abrasion resistance, certain other properties and specifications were required and are listed as follows:

1.1 Accelerated Ageing Specification

The treated webbing shall retain not less than 90% of the breaking strength of the untreated webbing after exposure to identical conditions in accordance with Paragraph 4.9.3.1, Specification MIL-W-4088B, as follows:

> "4.9.3.1 Accelerated Ageing - Five specimens of the resin treated webbing and five specimens of untreated webbing shall be exposed in the accelerated weathering unit as specified in Specification CCC-T-191 (National Weathering Unit).....Corex D filters and sunshine carbons shall be used. The exposure time shall be 100 hours. The spray heads shall be shut off during the entire exposure period. At the end of the exposure period the specimen shall be conditioned at 70°F. and 65% R.H. for 24 hours prior to breaking strength tests".

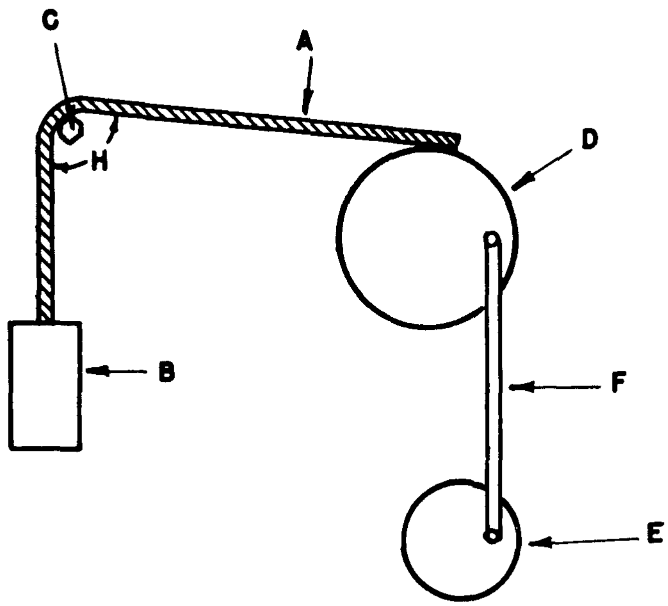
1.2 Abrasion Resistance Specification

The treated webbing shall retain not less than 90% of its original breaking strength after abrasion conducted in accordance with Paragraph 4.10.2 of Specification MIL-W-4088B, as follows:

> "4.10.2 Abrasion Test - Treated webbing shall be tested on the device shown schematically in Figure 1. The webbing A shall have one end attached to a 5.2 lb. weight B. The webbing shall pass over the hexagonal bar C and be attached to the oscillating drum D. The drum shall oscillate so that the webbing is given a 13 inch traverse over the bar at the rate of 60 plus or minus 2 strokes, the webbing shall be removed and the breaking strength shall be determined....."

1.3 Percent Extractibles Specification

The treated webbing shall contain that minimum amount of matter extractible with methyl ethyl ketone solvent as mentioned in Paragraph 4.10.3 of Specification MIL-W-4088B.



A - WEBBING

B - WEIGHT

C - 1/4 INCH HEXAGON ROD, ROCKWELL C18-22 HARDNESS

D - DRUM 16 INCH DIAM.

E - CRANK

F - CRANK ARM

H - ANGLE FORMED BY WEBBING 85° ± 2°

FIGURE 1

ABRASION TEST MACHINE

1.4 Flexibility Specification

The treated webbing shall be as flexible as the untreated webbing at -65°F., standard conditions, and after ageing tests. A suitable test to determine this flexibility quantitatively shall be developed.

1.5 Heat Stability Specification

The treatment on the webbing shall be heat stable at 350°F. The webbing shall be aged at 350°F., for 2, 6 and 16 hours to determine the effect on the following properties:

a. Breaking Strength

b. Flexibility

c. Abrasion Resistance

The same properties shall be obtained after cyclic exposure in 2 hour increments for 6 and 16 hours.

1.6 Weight and Thickness Specification

A weight increase up to 15%, and a change of not more than 15% in thickness shall be permitted in the treated webbings over the untreated.

II. GENERAL PLAN OF WORK:

Since the primary purpose of the desired finish was to increase the abrasion resistance of Dacron webbing, this property of untreated and treated webbings was investigated first. An abrasion tester as shown in Figure 1, was constructed for this purpose.

The general plan of the work was first to evaluate on the abrasion machine the various finishes which were considered. Those surviving this test were then evaluated at -65°F. for flexibility. A suitable test procedure for doing this was developed and will be described later. The treated webbings which had suitable low temperature flexibility were then heat aged, and those treatments surviving this heat ageing test were evaluated by exposure for 100 hours in the "weatherometer". The most satisfactory treatment according to these tests, was then applied at the Murdock Webbing Company, Pawtucket, Rhode Island, to 250 yards of scoured, heat stable webbing.

The dry resin pickup of the best treated webbings was far below the 15% limit and the determination of extractible material was therefore deemed unnecessary.

III. YARN PRODUCER'S FINISH - SCOURING:

The Dacron webbing used in this research was developed as part of another program 1/ as described in TR 55-135. It was learned here that it was necessary to remove the producer's yarn finish from the webbing for two reasons.

First, the finish might prevent good adhesion of any resin applied to the webbing. Second, the producer's finish was not heat stable; twenty four hours at 350°F. turned the webbing brown and markedly increased its stiffness. This stiffness appeared to be many times greater than would be caused by the abrasion resistant treatments planned in this work. Therefore, the webbing with the yarn producer's finish would have been unsuitable as a control to determine changes in flexibility due to application of an abrasion resistant finish.

Since manufacturers normally object to the use of solvent methods for the removal of the yarn producer's finish because of expense, fire hazard or toxicity, an aqueous scouring technique was employed. The finish was removed by use of the following detergent solution and conditions:

3 gms/liter Triton X-100 (Rohm and Haas Company)
Bath Ratio: 10/1
Temperature and Time 212°F., for 5 minutes

followed by thorough rinsing and drying in an oven.

This appeared to be a minimum time for a satisfactory commercial procedure.

IV. PRELIMINARY ABRASION TESTS:

Work was begun with 8700 lb. Dacron webbing received from Wright Air Development Center. Uniform abrasion across the width of this webbing was impossible to obtain in the preliminary work of this program.

After determining that the non-uniform abrasion was not due to faulty operation of the abrasion tester, a new lot of webbing was woven under different weaving conditions by the Murdock Webbing Company. This webbing was found to abrade more evenly. Further improvement in uniformity of abrasion was obtained by scouring with Triton X-100 before heat shrinking. As a result of this scouring, the webbing shrunk approximately half as much in both width and length as it would have in the normal 350°F., heat shrinking treatment (Table I). This scouring treatment therefore not only removed the finish but also caused one half the total shrinkage to take place in a lubricating medium (water) where the yarns could slip by one another as shrinkage occurred.

1/Kaswell, E.R., and Coplan, M.J., "Development of Dacron Parachute Materials" Wright Air Development Center Technical Report 55-135

TABLE I

COMPARISON OF METHODS OF SHRINKING 8700 LB. DACRON WEBBING

	As Received	Unscoured, Heated at 350°F For 1/2 Hour	Scoured at 212°F for 5 Minutes	Scoured plus 350°F for 1/2 Hour
Width in inches	2.02	1.75	1.90	1.75
Length in inches	36[a]	28.52	31.60	28.25
Thickness in inches	0.0893	0.1404	0.1230	0.1354
% shrinkage in width		13.4	5.95	13.4
% shrinkage in length		20.8	12.2	21.5
% increase in thickness		57.2	37.6	51.5

[a] Measured length taken for tests.

As a result of this partial shrinkage during the scouring cycle, the remaining shrinkage which was effected by the subsequent heat setting at 350°F. took place in a more uniform manner. This two-step heat treatment consequently produced a webbing that abraded uniformly over the entire abraded area and made it possible to evaluate finishes satisfactorily.

V. POTENTIAL ABRASION RESISTANT FINISHES:

It will be obvious that there are literally thousands of resin finishes available for consideration in such an investigation. At the outset of the research it was agreed by Wright Air Development Center and Fabric Research Laboratories, Inc., personnel that as complete a representation of basic commercial types of resin finishes as possible be investigated. The following list therefore encompasses the types of resins studied.

Product	Manufacturer
Silastic 131 Dispersion. No literature available. Solvent (xylene) dispersion of a silicone.	Dow Corning Corporation
DC 102 silicone emulsion (40% solids) used with catalyst emulsion XEY 21	Dow Corning Corporation
DC 104 silicone emulsion (40% solids) used with catalyst emulsion XEY 21.	Dow Corning Corporation
DC 105 silicone emulsion (40% solids) used with catalyst emulsion XEY 21.	Dow Corning Corporation
DC 108 silicone emulsion (40% solids) used with catalyst emulsion XEY 21.	Dow Corning Corporation
DC 112 silicone emulsion (40% solids) used with catalyst emulsion XEY 21.	Dow Corning Corporation
SE 100s. Soft, white silicone rubber compound 35% solution in xylene; long heat life, properties constant over wide temperature range.	General Electric Company
SM 70. Methyl silicone, fluid polymer dispersed in water.	General Electric Company
SE 76. Colorless, gum silicone polymer. Temperature use range -70°F. to +600°F. with flexibility down to approximately -85°F.	General Electric Company

Product	Manufacturer
SE 51. Light amber to colorless gum silicone polymer. Temperature use range -120°F. to +600°F. with flexibility down to approximately -120°F.	General Electric Company
SE 30. Low volatile silicone gum. Properties similar to SE 76. SE 30 preferred to SE 76 for cloth coatings.	General Electric Company
Silicone 81432 emulsion used with catalyst emulsion.	General Electric Company
#1572 Hycar Latex 42.6% solids. Medium acrylonitrile rubber dispersion good abrasion resistance and low temperature flexibility. #1714 Hycar Latex (21.1% solids) experimental, not being manufactured.	B.F. Goodrich Chemical Co.
Merlon BR. Polyvinyl butyral - butyl ricinoleate dispersion. Presently accepted finish for nylon webbing MIL-W-4088. Used as a yardstick for comparison.	Shawinigan Resins Corporation (Monsanto Chemical Company)
T-546 and T-622, acrylic resin dispersions. Maximum abrasion resistance reported with use of T546. Low temperature flexibility increased by addition of T-622 with accompanying decrease in abrasion resistance. (Experimental Resins)	Rohm and Haas Company
BIND-404-M2-1. Natural rubber latex reported to have good low temperature flexibility.	Rubber Corporation of America

The following products were considered as possible coating materials and rejected for the reasons stated below:

Product	Manufacturer
Mylar. Dacron film which would have to be applied by melting on. Since the melting point is the same as the Dacron webbing this	E.I. duPont deNemours & Co.

Product	Manufacturer
possibility was ruled out. By the same token any possible solution of Dacron was rejected since such a solution would also dissolve the Dacron webbing and cement it into a stiffer structure.	
Alcohol Soluble Nylon. Ruled out because of instability at high temperatures and sensitivity to ultraviolet light.	E. I. duPont deNemours & Co.
Teflon. A tetrafluoroethylene polymer high melting point, cannot be applied through solvent or emulsion systems. The monomer is gaseous under normal conditions, the use of pressure being necessary to convert it to a solid.	E. I. duPont deNemours & Co.
Kel-F. A trifluorodichloroethylene polymer. Available as a dispersion which requires a cure at 480°F., the melting point of Dacron.	M. W. Kellogg Company
Polyvinyl chloride, polyvinyl chloride - acetate resins, as organosols or plastisols; may require fusion temperatures up to 350°F. Treated webbing must withstand 16 hours at 350°F. which ruled out these resins.	Firestone Plastics Company Carbide & Carbon Chemicals Corp.
Silastic S2007. A silicone paste requiring a curing temperature of 390°F. for 2 to 4 hours. This long curing time was considered impractical for this webbing application.	Dow Corning Corporation

The above lists will serve to illustrate the type of resins considered. In general, these were resins with properties as reported by the manufacturer, which indicated some promise of obtaining a treated webbing with the desired characteristics. Resins such as phenolics or melamines generally used for casting solid objects, or used in combination with drying oils were not considered. Resin mixes requiring searching for plasticizers which would give good flexibility at -65°F. and stability at 350°F. were avoided on the basis of the possible long time involved. Resins requiring extended and impractical curing times or the use of inflammable or toxic solvents were not considered in view of the promising aqueous resin emulsions available.

In view of the delay at the start of this program in obtaining uniform abrasion of the untreated webbing, the above list of resins, favorably considered, seemed to offer the greatest chance of obtaining a satisfactory treatment and thorough evaluation in the alloted time.

VI. MEASUREMENT OF FLEXIBILITY:

A requirement of this program was the development of a suitable quantitative flexibility test of the webbings at both room temperature and at -65°F. The following discussion reviews the test methods considered, the factors pertinent to the selection, and the details and considerations of the method selected.

6.1 Flexibility and Stiffness, General

Flexibility, the ease with which a material specimen may be bent, is a physical property that can be evaluated subjectively by means of the sense of feel as either sufficiently flexible or not for a particular end use. Although this subjective evaluation includes allowance for additional factors, the physical property usually measured in the laboratory for purposes of description of the material is the stiffness of a specimen under prescribed conditions.

Eshbach[1] defines stiffness as "The ability to resist deformation under stress. The modulus of elasticity is the criterion of the stiffness of a material". The adaptation of this definition from classical mechanics to textile materials has been a subject of much study by textile engineers. Peirce[2] in his paper "The Handle of Cloth as a Measurable Quantity" discusses methods for measuring fabric stiffness, starting with reasoning on fundamentals. Others have approached the problem semi-empirically by devising instruments and demonstrating their usefulness.

6.2 Stiffness Measurement Methods

The following is a list of methods and instruments for measuring stiffness which have been devised and used for textile materials:

1. The bending length, c, (Peirce) as measured by means of:

    a. Rectangular cantilever

        i. "Dynamic" (i.e., measurement of overhanging length needed to be moved out to deflect the chord joining the cantilever ends through a predefined angle).

1/Eshbach, Handbook of Engineering Fundamentals p5-07, John Wiley & Sons.
2/Peirce, F.T., Journal of the Textile Institute, 21, T377, (1930).

ii. "Static" (i.e., measurement of the chord deflection angle formed by an arbitrarily fixed length of overhang).

b. Weighted Rectangle
c. Circular Cantilever
d. Hanging Heart
e. Triangular Cantilever
f. Weighted Triangle
g. Pear-Loop Cantilever
h. Hanging Loops

2. The Flexural Rigidity, G

3. The Gurley Stiffness Tester

4. The Schiefer Flexometer

5. The Clark Softness Tester

6. The Olsen Stiffness Tester

Among the methods mentioned above, both the Dynamic and the Static Rectangular Cantilever methods have been tried. Acceptable test results from these methods, along with other considerations, permitted rejection of the remaining methods.

Methods 3 through 6 are instruments or devices which give no more information than the simpler method selected. Further, these special instruments are known to have sometimes shown poor agreements among each other for a variety of reasons.

The direct measurement of the bending length as defined by Peirce is the simplest method for measuring stiffness as well as being the most adaptable to a variety of textile materials and conditions. Further, the mere additional measurement of weight and area, will convert the results by calculation to method 2, Flexural Rigidity, G, which is really not a method of testing so much as a method of expressing results to describe flexibility.

The other methods of determining the bending length, e.g., 1.b through 1.h were derived by Peirce to meet special requirements, such as minimizing curl, going further into the lower range of stiffness, etc., but at the sacrifice of simplicity.

The use of the rectangular cantilever method of determining the bending length of the webbing under study has been found to require a certain sequence of operations in order to allow for the tendency of behavior. These details will be appreciated from the test descriptions following, and will be summarized in the description of method for performing the tests.

6.3 Materials Used for Methods of Evaluation

In order to "sense" the numerical results from the preliminary work, three conditions of the webbing were selected as representing the range of flexibility to be encountered. Three samples of each specimen were taken to estimate reproducibility. These specimens were:

Specimen 1 — The 8700 lb. test webbing, as received, prior to heat shrinkage to specified dimensions. This represented the obviously lowest stiffness for this structure.

Specimen 2 — Material described as Specimen 1 after heat shrinkage and "breaking" (flexing to reduce temporary stiffness). This untreated webbing represented a practical intermediate value of stiffness of a magnitude close to that sought in the treatment evaluation program.

Specimen 3 — Material described as Specimen 2, but treated with a resin and cured, the treatment being excessive so as to cause an extreme of stiffness.

6.4 Measurement of Bending Length of Webbing

In Peirce's original work there probably was no distinction made of "Dynamic" or "Static" conditions in considering the rectangular cantilever test. The test is described merely as the extending of a portion of a long, narrow, rectangular strip over a horizontal edge followed by measuring both the length of overhang and also the deflection angle between the horizontal and the chord joining the ends of the specimen. These two quantities are interrelated to give the bending length, thus:

$$c = \ell f_1 \ (\theta)$$

and

$$f_1 \ (\theta) = (\cos 0.5\theta / 8 \tan \theta)^{1/3}$$

c = the bending length
ℓ = the length of overhang
θ = the deflection angle between the horizontal and the chord joining the ends of the overhanging length.

The values calculated for f_1 (θ) can be tabulated or graphed for convenient use. However, it was noted that if an angle θ was pre-selected for which f_1 (θ) equaled 0.5, then the bending length could be found more easily without resort to tables of graphs. If the strip of cloth to be tested was gradually moved out over the horizontal edge until it formed a deflection angle of about 43°, the value of θ for which f_1 (θ) equals 0.5, then one half the overhanging length, ℓ, equals the bending length, c.

The derivation of this relationship between the angle and the overhanging length to give the bending length involves several assumptions concerning the mechanics of the factors influencing fabric stiffness. Two important assumptions necessary to appreciate for the application of this test to webbing are:

1. The specimen is assumed to be a uniform lamina. in which the curvature is proportional to the bending length.

2. No visco-elastic phenomena are present.

This Dacron webbing clearly does not meet these assumptions, so the selection of this method of measuring webbing stiffness must include allowance for some deviation from a true stiffness value. Inference from the data to be shown later suggests the possible relationship,

$$c = F\left[\ell f_1 \ (\theta)\right]$$

in which the function F of ℓf_1 (θ) is probably dependent on the length of overhang for a particular stiffness range. An empirical solution of this situation appears to have been found. See Section 6.6.

The results of bending length measurements on the three typical specimens by both "Dynamic" and "Static" rectangular cantilever methods can now be given to illustrate the necessity for the details of the procedure selected.

6.5 "Dynamic" Rectangular Cantilever Method

If the convenient pre-selected angle of 43° is used to determine the bending length, the physical performance of the test consists of pushing a rectangular strip over a horizontal edge until the chord deflects down to an index mark at 43°. In the ordinary textile measurement the only limit to the speed at which the strip is moved out is the ability of the observer to follow the movement of the overhanging tip as it approaches the pre-selected angle. For a low order of stiffness, a fairly rapid movement is permissible. For a stiffer fabric it is conceivable that the rate of forward movement of the strip can permit a buildup of downward momentum that would cause the angle to be overshot for the amount of fabric that had been extended. Thus, there is a maximum speed of movement for the stiffer fabrics. For a material as stiff as Specimen 3, a very low rate of movement must be used to prevent error from this effect. For this reason two methods, "fast" and "slow" were used to measure the treated specimens.

Table II gives the raw data for the overhanging length, ℓ, necessary to deflect the chord 43°. Each sample of a specimen yields four readings, one from each side of each end. Since readings 1 and 3 represent

TABLE II

MEASURED OVERHANGING LENGTH, ℓ, BY "DYNAMIC" RECTANGULAR CANTILEVER METHOD

Specimen 1, As Received

Reading No.		Sample 1	Sample 2	Sample 3	Grand Mean	Bending Length, c
1		5.65"	4.55"	5.35"		
2		4.65"	5.55"	4.50"		
3		5.65"	4.60"	5.40"		
4		4.65"	5.50"	4.60"		
	Ave.	5.15"	5.05"	4.96"	5.05"	2.52"

Specimen 2, Untreated

Reading No.		Sample 1	Sample 2	Sample 3	Grand Mean	Bending Length, c
1		5.50"	4.85"	5.70"		
2		4.50"	5.80"	5.15"		
3		5.60"	4.65"	5.75"		
4		4.50"	5.85"	5.15"		
	Ave.	5.02"	5.29"	5.44"	5.25"	2.62"

Specimen 3, Treated - "Fast"

Reading No.		Sample 1	Sample 2	Sample 3	Grand Mean	Bending Length, c
1		9.50"	10.65"	11.50"		
2		11.00"	11.25"	9.60"		
3		9.70"	10.35"	11.25"		
4		11.40"	12.50"	11.80"		
	Ave.	10.40"	11.19"	11.04"	10.88"	5.44"

Specimen 3, Treated - "Slow"

Reading No.		Sample 1	Sample 2	Sample 3	Grand Mean	Bending Length, c
1		6.60"	7.00"	6.00"		
2		8.00"	8.00"	8.00"		
3		6.00"	7.00"	7.00"		
4		8.00"	8.00"	8.00"		
	Ave.	7.15"	7.50"	7.25"	7.28"	3.64"

TABLE III

CALCULATION OF "CURL" AND "ANTI-CURL" BENDING LENGTHS FROM "DYNAMIC" RECTANGULAR CANTILEVER MEASUREMENTS

	Specimen 1		Specimen 2		"Fast" Specimen 3		"Slow" Specimen 3	
	Curl	Anti-Curl	Curl	Anti-Curl	Curl	Anti-Curl	Curl	Anti-Curl
Sample 1	4.65	5.65	4.50	5.50	9.50	11.00	6.60	8.00
Sample 1	4.65	5.65	4.50	5.60	9.70	11.40	6.00	8.00
Sample 2	4.55	5.55	4.85	5.80	10.65	11.25	7.00	8.00
Sample 2	4.60	5.50	4.65	5.85	10.35	12.50	7.00	8.00
Sample 3	4.50	5.35	5.15	5.70	9.60	11.50	6.00	8.00
Sample 3	4.60	5.40	5.15	5.75	11.80	11.25	7.00	8.00
Ave.	4.59	5.52	4.80	5.70	10.26	11.48	6.60	8.00
c	2.30"	2.76"	2.40"	2.85"	5.13"	5.74"	3.30"	4.00"
Mean c	2.52"		2.62"		5.44"		3.64"	

the stiffness in one direction, and the readings 2 and 4, obtained by turning the sample over, the stiffness in the other direction, it can readily be seen that there is a preferential direction of curl in all samples. This may be the result of permanent set acquired by the yarns during weaving due to being wound off the machine under high warp tension. Another possibility may be a set produced by forced slippage of fibers and yarns over one another during a processing step such as shrinking, in a curled or bent state. Whatever the cause, it appeared advisable at this stage to re-sum the data so as to report a "curl" and "anti-curl" value of the bending length, as well as the mean value. This is done in Table III.

Referring back to Table II, there are two sets of determinations for the treated specimen referred to as "fast" and "slow". These terms are merely relative since even the "fast" test results were obtained by sliding the fabric out at approximately only one foot per minute in order to prevent the sluggish bending from overshooting. Even so, after several minutes the end of the webbing was resting hard on the 43° angle index plate. Further, an attempt the next day to duplicate the rate of movement of the first trial resulted in all values of the overhanging length, ℓ, being 2 to 4 inches greater.

Since it did not appear feasible manually to move the sample slower, an approximation of a slower rate that could be reproduced was devised. That is, the sample was moved out in increments of one inch at a time in timed one-minute intervals. The "slow" data show the result, but what is not visible is that the tip reached the 43° angle at varying intervals from 0 to 60 seconds after the last inch increment of overhang was added. Although this method, too, was unsatisfactory, it did show the widely different values of stiffness that could be obtained if the visco-elastic tendencies of the treated webbing were ignored.

6.6 "Static" Rectangular Cantilever Method

Measurement of the deflection angle formed by the chord of a fixed length of overhang with the horizontal will also yield a value of the bending length, c, by reference to a table or graph (Figure 2) relating the measured angle θ to $f_1(\theta)$. Marks were made on each of the nine samples at 3 inches and 6 inches from each end to obtain two sets of data for "static" measurements at two lengths of overhang. The samples were then merely pushed out this pre-selected length at a rate slow enough to avoid downward momentum effects. The angular readings were taken after a five minute waiting period, at which time no further movement of the webbing was noticeable. These results are shown in Table IV, and the results are regrouped in Table V to give the "curl" and "anti-curl" stiffness.

Interpretation of these last two tables is easier with the aid of Table VI which compares the values of the bending lengths as measured by both methods. The lack of correlation between the "Dynamic" and "Static" methods led to the following experiment.

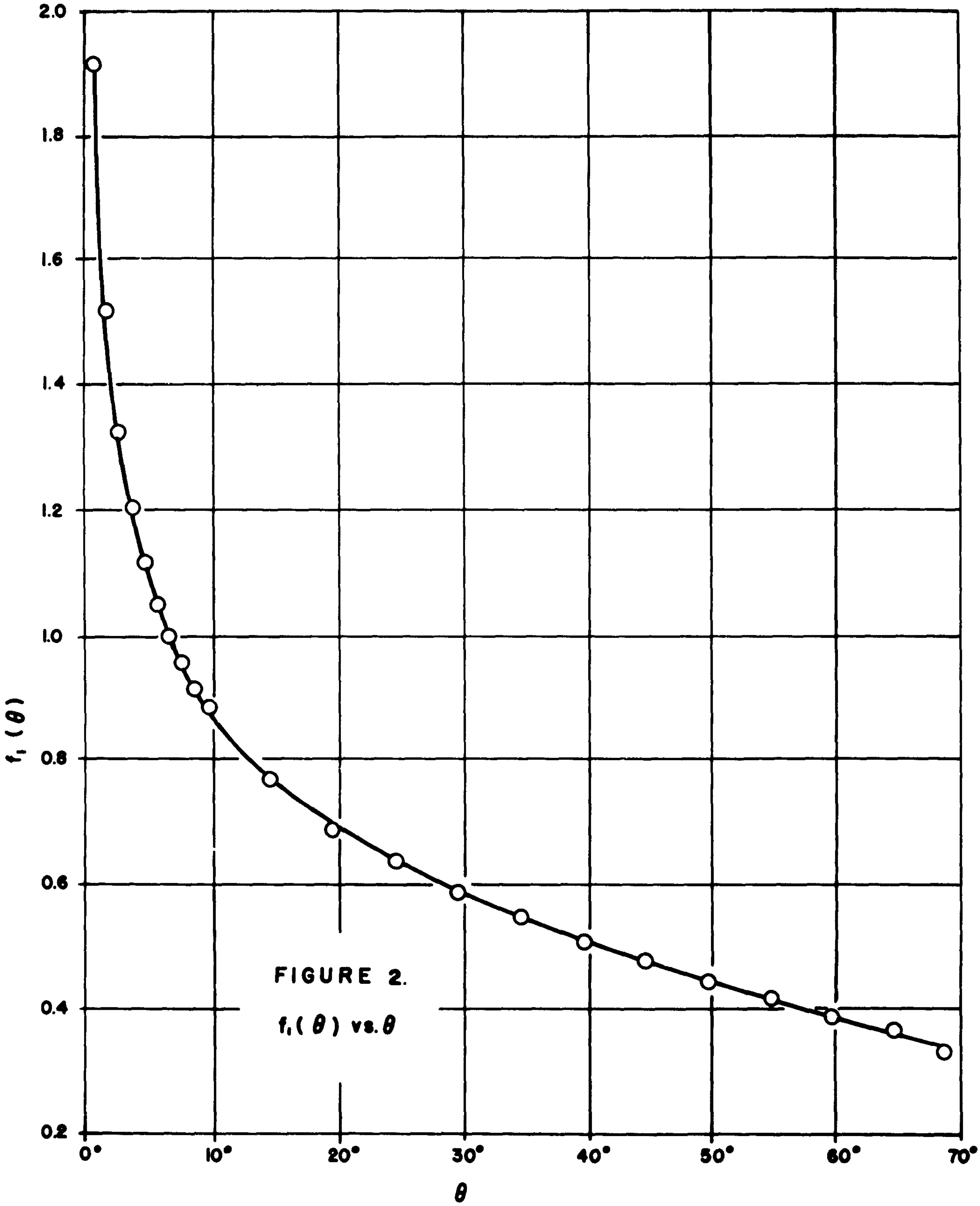


FIGURE 2.

$f_1(\theta)$ vs. θ

WADC TR-55-313

TABLE IV

MEASURED ANGLE, θ, BY "STATIC" RECTANGULAR CANTILEVER METHOD

	ℓ = 3"					ℓ = 6"				
	1	2	3	θ	c	1	2	3	θ	c
Specimen 1										
1	3	6	6			67	70	70		
2	2	0	0			72	65	67		
3	0	5	3			67	70	70		
4	5	0	0			75	65	67		
Ave.	2.5°	2.75°	2.25°	2.5°	4.23"	70°	68°	68°	68.7°	2.07"
Specimen 2										
1	10	8	5			50	51	49		
2	8	13	10			58	64	62		
3	8	8	8			51	55	50		
4	10	11	14			58	63	62		
Ave.	9°	10°	9.25°	9.4°	2.75"	54.25°	58.25°	55.75°	56°	2.52"
Specimen 3										
1	Too small an angle to measure					42	40	30		
2						17	26	30		
3						35	44	25		
4						25	26	58		
Ave.						29.75°	34°	35.75°	33°	3.42"

TABLE V

CALCULATION OF "CURL" AND "ANTI-CURL" BENDING LENGTHS FROM "STATIC" RECTANGULAR CANTILEVER MEASUREMENTS

	ℓ = 3"				ℓ = 6"					
	Specimen 1		Specimen 2		Specimen 1		Specimen 2		Specimen 3	
	Curl	Anti-Curl	Curl	Anti-Curl	Curl	Anti-Curl	Curl	Anti-Curl	Curl	Anti-Curl
Sample 1	2	3	8	10	72	67	58	50	42	17
Sample 1	5	0	10	8	75	67	58	51	35	25
Sample 2	6	0	13	8	70	65	64	51	40	26
Sample 2	5	0	11	8	70	65	63	55	44	26
Sample 3	6	0	10	5	70	67	62	49	30	30
Sample 3	3	0	14	8	70	67	62	50	58	25
	4.5°	0.5°	11°	7.8°	71°	66°	61°	51°	42°	25°
c	3.48"	6"	2.61"	2.91"	1.92"	2.10"	2.34"	2.70"	3.00"	3.84"
Mean c	4.23"		2.75"		2.07"		2.52"		3.42"	

TABLE VI

COMPARISON OF BENDING LENGTHS C DETERMINED BY "STATIC" AND "DYNAMIC" RECTANGULAR CANTILEVER METHODS

	Bending Length c			
	"Dynamic"		"Static"	
Specimen 1			when ℓ = 3"	ℓ = 6"
Curl	2.30		3.48	1.92
Anti-Curl	2.76		6.00	2.10
Mean	2.52		4.23	2.07
Specimen 2				
Curl	2.40		2.61	2.34
Anti-Curl	2.85		2.91	2.70
Mean	2.62		2.75	2.52
Specimen 3	"Slow"	"Fast"		
Curl	3.30	5.13	-	3.00
Anti-Curl	4.00	5.74	-	3.84
Mean	3.64	5.44	-	3.42

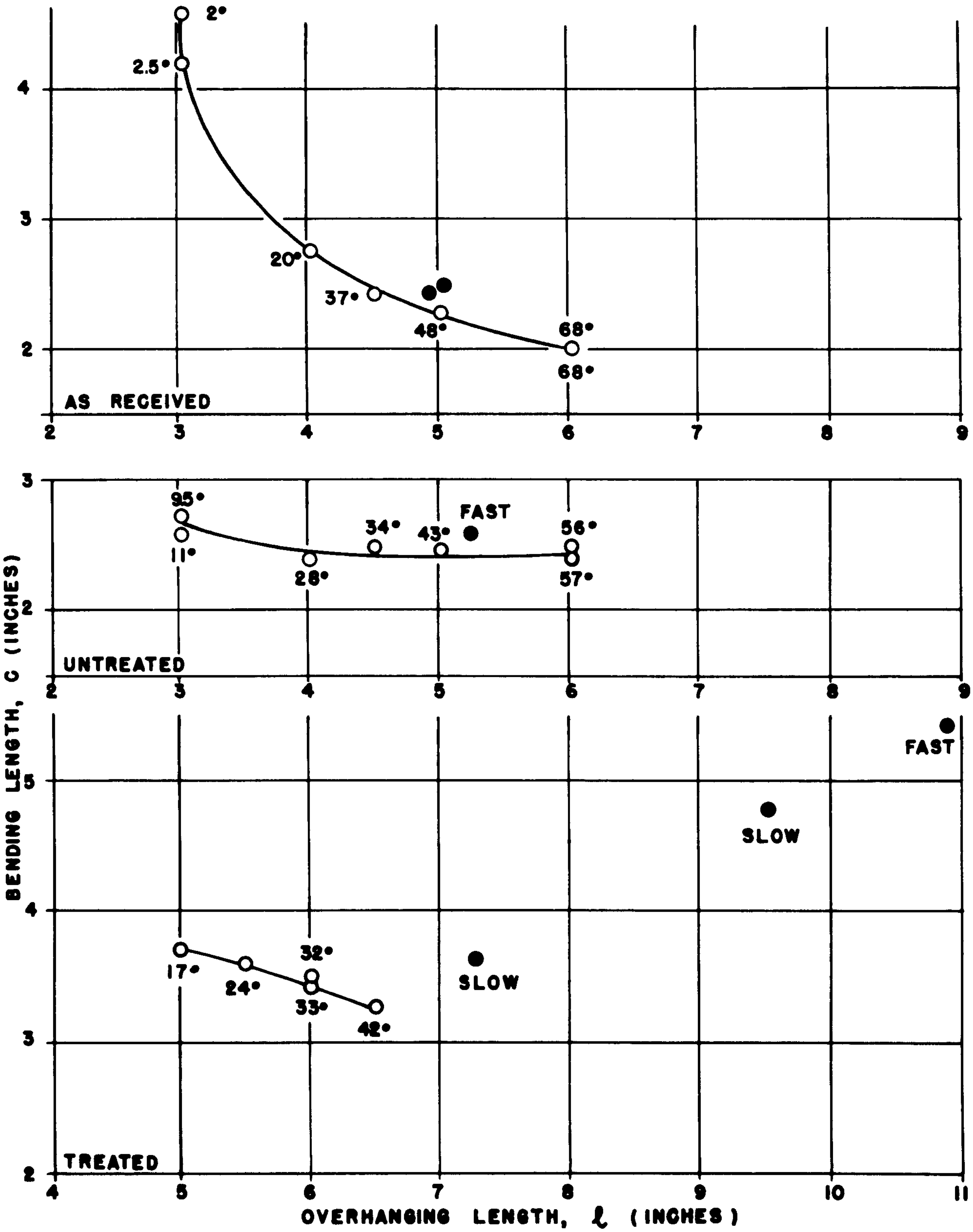


FIGURE 3.

COMPARISON OF "STATIC" MEASUREMENTS FOR VARIOUS OVERHANGING LENGTHS WITH "DYNAMIC" MEASUREMENTS.

O STATIC MEASUREMENT
● DYNAMIC MEASUREMENT

It was observed, when making the "Static" measurements, that the curves described by the bent sample at two different overhanging lengths were different. A relationship between the curve shape of the bent specimen and the principle of the bending length measurement was recognized, but the practical solution of the discrepancy appeared to be a series of measurements. "Static" measurements of each of the three specimens at several overhanging lengths were made, the results and the comparison with the "Dynamic" data are visible by inspection of Figure 3.

The best correlation of the two methods of measurements is apparent in the "untreated" specimen. However, general inspection indicates that if an overhanging length, ℓ, is chosen so that the deflection angle θ, falls between 20° and 40°, the best correlation between "Static" and "Dynamic" methods is obtained regardless of the stiffness range of the specimen being investigated.

When visco-elastic effects are present in the webbing, as in the "treated" specimen, it appears that the "Static" method gives more significant results.

6.7 Test Method for Determining Bending Lengths

As the research progressed, preference was expressed for the "Static" over the "Dynamic" method when the webbing appeared to show visco-elastic behavior. Subsequent work indicated that the two methods checked fairly well in this case if the rate of movement of the sample over the horizontal plane of the instrument was 1 foot per minute. The test method used in the remainder of the work was therefore the "Dynamic" one and was carried out as follows:

The test sample, 12 inches long, was placed on a horizontal base at one end of which was a plane surface making an angle of 43° with this horizontal. The webbing was then pushed over the end of the base at a rate of 1 foot per minute until the end of the overhanging webbing touched the 43° plane. Twelve readings of this overhanging length, ℓ, were taken, four from each of three samples from the same specimen of webbing. One half of the mean of these 12 values was taken as the bending length, c.

6.8 Flexural Rigidity, G

Another method of expressing the stiffness is by means of the flexural rigidity, G. This parameter of stiffness can be calculated by merely determining the weight per unit area, in addition to the bending length, c. It is calculated from the following expression:

$$G = \rho c^3$$

where ρ = weight/unit area (gms/cm.^{2})
c = the bending length (centimeters)
G = the flexural rigidity (gmsxcm[illegible])

The values of stiffness described by this parameter approach more closely the effect that would be felt by bending the webbing forcibly between the forefinger and thumb of two hands.

6.9 Low Temperature Test Equipment

A well insulated test chamber was constructed with a plexiglas window in one side for viewing the interior and operation of the stiffness test. An insulated, loose fitting, stepped cover afforded easy access to the interior. To obtain a temperature of -65°F. cold air from a Tenney cabinet was blown in one end, circulated and returned to the Tenney cabinet.

The Tenney cabinet was a commercial unit provided with controls and a blower for circulating air over dry ice out to a test chamber and return. The blower operated continuously and the temperature was controlled by means of a thermostatically operated damper which by-passed some of the air over simultaneously controlled heaters instead of over the dry ice. The thermostat was adjusted according to the temperature of the return air stream from the test chamber as determined by a thermocouple. By this means a chosen low temperature could be controlled within 3°F. Before any measurements of the bending length were made, care was taken to make sure that an equilibrium condition at -65°F. had been attained.

The "Dynamic" bend tester used in the chamber consisted of a vertically supported piece of plywood supporting a horizontal, polished aluminum platform plate. The aluminum platform was slightly larger than the 1 3/4" x 12" sample of webbing to be tested. The vertical plywood support extended beyond the end of the platform and this extension was at the platform end so that a 43° angle was formed with the horizontal. The sample was pushed out at a slow rate (1 foot per minute, or less) over the leading edge of the aluminum platform by a flat, weighted wooden shoe faced with sandpaper to prevent slippage when resting on the sample. The device was operated inside the test chamber by means of a long wooden dowel rod which extended through the wall of the cabinet and was used to push the sliding shoe and sample over the platform. When the leading end of the webbing touched the 43° angle edge, the distance the dowel rod had been moved was determined by means of inch gauge marks on the dowel rod.

Dimensions of the tester and the test chamber were such that the maximum overhanging sample length, without appreciable bending was nine inches (limit of test). The maximum overhanging length measurable on a more flexible sample was about 12 inches. This gave a maximum measurable bending length, c, of 6.0 inches. Any sample stiffer than this would certainly not pass the specifications.

6.10 Bending Test Results

Table VII lists the bending length, c, at room temperature and at -65°F. for three reference samples and twelve experimentally treated webbings.

TABLE VII

COMPARISON OF BENDING LENGTHS, c, DETERMINED AT ROOM TEMPERATURE AND -65°F

Sample	Material	Dry Pick-Up (%)	"Dynamic" Bending Length, c Rm. Temp. (in.)	"Dynamic" Bending Length, c -65°F (in.)
Reference Samples				
A.	"As Rec'd" (Before scour & heat shrinkage)	-	2.52	2.82[a]
B.	"Untreated"-Control (Scoured & heat shrunk)	-	2.62	2.58
C_1	(Heat shrunk, not scoured)	-	4.19	5.48[a]
C_2	(Heat shrunk, not scoured)	-	3.42	4.52[a]
Treated Samples				
I	Rubber Co. of Amer. BIND 404-M2-1	1.41	3.26	3.98
II	Rubber Co. of Amer. BIND 404-M2-1	1.95	3.54	4.96
III	Rohm & Haas T-546-LM-291	2.9	3.91	over 6
IV	Rohm & Haas T-546-LM-291	2.6	4.04	over 6
V	Hycar 1572	2.6	3.86	over 6
VI	Hycar 1572	2.5	3.98	over 6
VII	Hycar 1572 & Curing Agent	2.6	4.17	over 6
VIII	Hycar 1572 & Curing Agent	2.5	4.16	over 6
IX	Hycar 1714	2.1	3.36	over 6
X	Hycar 1714	2.0	3.46	over 6
XI	Hycar 1714 & Curing Agent	2.1	3.70	over 6
XII	Hycar 1714 & Curing Agent	2.2	3.68	over 6

[a] visco-elastic tendencies

TABLE VIII

COMPARISON OF FLEXURAL RIGIDITY, G, DETERMINED AT ROOM TEMPERATURE AND -65°F

Sample	Material	Dry Pick-Up (%)	"Dynamic" Flexural Rigidity, G Rm. Temp. (gms x cms)	-65°F (gms x cms)
Reference Samples				
	"As Rec'd" (Before scour & heat shrinkage)	-	44	66[a]
	"Untreated"-Control (Scoured & heat shrunk)		76	72
A	(Only heat shrunk)		314	704[a]
B	(Only heat shrunk)		171	395[a]
Treated Samples				
I	Rubber Co. of Amer. BIND 404-M2-1	1.41	152	276
II	Rubber Co. of Amer. BIND 404-M2-1	1.95	199	548
III	Rohm & Haas T-546-LM-291	2.9	267	over 1000
IV	Rohm & Haas T-546-LM-291	2.6	294	over 1000
V	Hycar 1572	2.6	253	over 1000
VI	Hycar 1572	2.5	278	over 1000
VII	Hycar 1572 & Curing Agent	2.6	318	over 1000
VIII	Hycar 1572 & Curing Agent	2.5	314	over 1000
IX	Hycar 1714	2.1	168	over 1000
X	Hycar 1714	2.0	184	over 1000
XI	Hycar 1714 & Curing Agent	2.1	223	over 1000
XII	Hycar 1714 & Curing Agent	2.2	220	over 1000

[a] Visco-elastic tendencies

It is important to note the effect of the yarn producer's finish on flexibility. It apparently undergoes some change during heat shrinking which makes the webbing stiffer at room temperature and at -65°F. (samples c_1 and c_2 versus samples A and B).

Five of the six treatments applied, produced webbing with a bending length greater than 6.0 inches at -65°F. and were regarded as unsatisfactory.

Table VIII lists flexural rigidity values, G, of the same samples. Those with a value of G at -65°F. of over 1,000 were considered too stiff. The reversal of the relative stiffness of samples A and B (Table VIII vs. Table VII) is due to the greater value, in the case of the shrunk sample, of the weight per unit area, ρ, which is a factor in calculating G. On the basis of these results it was considered that a satisfactory method had been developed for quantitatively comparing the flexibility of samples of webbing.

VII. EVALUATION OF CERTAIN RESIN EMULSION TREATMENTS:

7.1 Preparation of Webbing

The webbing was first scoured in the Triton X-100 solution (3 gms/liter bath ratio 10/1) for five minutes at 212°F., thoroughly rinsed and then dried. Following this it was allowed to shrink in an oven at 350°F. for 1/2 hour. Total shrinkage caused by scouring and heating at 350°F. was 21.5% in the length and 13.5% in the width. The samples were conditioned and weighed in order that resin pickup might be determined later.

7.2 Application of Emulsions

The resin emulsions listed in Table IX were applied to webbing samples by means of a two roll, 10 inch Butterworth padder having a top roll of rubber and the bottom one of stainless steel. A minimum roll pressure was used. After drying or curing as noted below, the samples were conditioned and weighed. Pickup was varied by changing the resin solids in the pad bath.

The objective was the application of that minimum amount of resin which would provide the desired abrasion resistance. This was conducive to obtaining the maximum flexibility of a treated webbing at standard conditions -65°F. and after heat ageing at 350°F.

7.3 Testing of Treated Webbings

The evaluation of the finishes was planned so as to first use the tests which were easily performed and which at the same time were most likely to cause the performance of the treated webbing to fail. If a finish successfully passed a test, it was allowed to continue to the next. When a sample failed to meet a required specification, no further testing was carried out.

The following sequence of tests was followed:

1. Abrasion resistance - as determined by the abrasion machine and tensile tester.
2. Flexibility at standard conditions.
3. Flexibility at -65°F.
4. Flexibility after ageing 2 hours at 350°F.
5. Flexibility after ageing 6 hours at 350°F.
6. Flexibility after ageing 16 hours at 350°F.
7. Exposure for 100 hours in weatherometer.

In order to conserve webbing, reduce the number of treated samples necessary and thus expedite the work of rough screening the resin emulsion treatments, the same samples of webbing, after being tested for flexibility at standard conditions, were subsequently aged at 350°F. for 16 hours, room temperature flexibility being measured at the end of 2, 6 and 16 hours. This procedure may not have given an accurate indication of the decrease in flexibility due to heat ageing from 0 to 6 and 0 to 16 hours because of the flexing of the webbing during the testing after 2, and 6 hours. However, if the webbing was found to be too stiff after 2 hours or 6 hours ageing, further ageing and testing was not carried out and absolute accuracy of the flexibility determination was not important.

If a treatment passed the heat ageing tests, more samples with this treatment were then prepared for accurate flexibility determinations at each heat ageing station and for "weatherometer" tests.

7.4 Discussion of Results in Table IX

It can readily be seen (Groups 1 and 2 in table) that scouring the webbing before heat shrinking produced a webbing more flexible at standard conditions, -65°F., and after heat ageing at 350°F., than one which was heat shrunk without scouring. This difference in flexibility was greatest at -65°F.

Samples of webbing treated with Rohm and Haas T546 acrylic emulsion (Group 3, 2.6 to 2.9% pickup) were too stiff at -65°F. Although this might have been improved by admixture of some T622 acrylic resin, this would have lowered the abrasion resistance which was already below the specified value. For this reason as well as the color change and extreme stiffness after two hours at 350°F., no further consideration was given these resins.

TABLE IX

THE EFFECT OF ABRASION, TEMPERATURE AND AGEING AT 350°F. ON 8700 LB. DACRON WEBBING AFTER TREATMENT WITH VARIOUS RESIN FINISHES

							Flexibility Measurements									
							At Standard Conditions		At -65°F.		After Being Heat Aged at 350 F. For: 2 Hours		6 Hours		16 Hours	
Finishes Used	Group	Resin Bath Solids (%)	Dry Pickup (%)	Abrasion Cycles	Breaking Strength After Abrasion (lbs.)	Strength Retained % of Original	C	G	C	G	C	G	C	G	C	G
Controls - scoured and heat shrunk at 350°F.	1			None	8715^a		2.09^c	76^c	2.68^c	85^c	5.05^c	565^c	5.33^c	663^c	5.85^c	670^c
				5000	3918^d	44.9										
Control - heat shrunk only at 350°F. without scouring	2						3.01^c	117^c	5.55^c	737^c	5.85^c	855^c	5.92^c	888^c	5.86^c	860^c
T-546-LM-291 Rohm & Haas (Acrylic Emulsion) 20 min. at 275°F.	3	26.0	11.6	5000	6700	76.8										
		13.5	5.6	5000	7090	81.3										
		7.8	3.4	5000	7290	83.6										
		7.8	2.9				3.91^b	267^b	over 6^b	over 1000^b	(After the first 2 hours heat ageing at 350°F. samples turned brownish (yellow and were too stiff to be tested for flexibility.					
		7.8	2.6				4.04^b	294^b	over 6^b	over 1000^b						
BIND-404-M2-1 Rubber Corp. of America (Natural Rubber Latex) 1st 3 samples - 20 min. 275°F. 2nd 3 samples - 20 min. 212°F.	4	29.0	10.8	5000	7670	88.0										
		14.5	5.4	5000	8000	91.7										
		8.7	1.8	5000	8470	97.1										
		5.8	1.7	5000	8880	101.8										
		8.7	1.4				3.26^b	152^b	3.98^b	276^b	(After the first 2 hours heat ageing at 350°F. samples turned (brown and were too stiff to be tested for flexibility.					
		8.7	1.95				3.54^b	199^b	4.96^b	548^b						
Hycar 1714 B. F. Goodrich Chemical Co. (Latex) 20 min. 219°F.	5	15.8^e	3.9	5000	—Jaw Slippage—											
		15.8^f	4.5	5000	—Jaw Slippage—											
		10.5^e	4.1	5000	7260	83.3										
		10.5^f	2.9	5000	—Jaw Slippage—											
		8.4^f	2.0				3.46^b	184^b	over 6^b	over 1000^b	(After the first 2 hours heat ageing at 350°F. samples turned (a dark brown and were too stiff to be tested for flexibility.					
		8.4^e	2.2				3.68^b	220^b	over 6^b	over 1000^b						

a Average of two samples tested
b Average of three samples tested
c Average of six samples tested
d Average of eight samples tested
e With curing agent
f Without curing agent
C Bending length C
G Flexural rigidity G

TABLE IX (Cont'd.)

THE EFFECT OF ABRASION, TEMPERATURE AND AGEING AT 350°F. ON 8700 LB. DACRON WEBBING AFTER TREATMENT WITH VARIOUS RESIN FINISHES

Finishes Used	Group	Resin Bath Solids (%)	Dry Pickup (%)	Abrasion Cycles	Breaking Strength After Abrasion (lbs.)	Strength Retained % of Original	Flexibility Measurements: At Standard Conditions c	G	At -65°F. c	G	After Being Heat Aged at 350°F. For: 2 Hours c	G	6 Hours c	G	16 Hours c	G
Hycar 1572	6	32.0^{f}	12.2	Too stiff to be abraded												
B. F. Goodrich Chemical Co.		21.3^{f}	8.5	5000	Jaw Slippage											
(Latex)		10.6^{f}	4.4	5000	6160	70.6										
20 min. at 219°F.		10.6^{e}	4.4	5000	7700	88.3										
		6.4^{f}	2.6	5000	7260	83.3										
		6.4^{e}	2.1	5000	8220	94.3					(After the first 2 hours heat ageing at 350°F. samples turned a dark brown and were too stiff to be tested for flexibility.					
		6.4^{f}	2.5				3.98^{b}	278^{b}	over 6^{b}	over 1000^{b}						
		6.4^{e}	2.5				4.16^{b}	314^{b}	over 6^{b}	over 1000^{b}						
Merlon BR	7	16.0	6.9	5000	8480	97.30										
Monsanto Chemical Company		8.0	2.9	5000	8740	100.0										
(Polyvinyl Butyral)		8.0	3.1	5000	8660	99.0										
12 min. at 249°F.		4.0	1.3	5000	8720	100.0	3.64^{b}	210^{b}	over 6^{b}	over 900^{b}	5.88^{b}	887^{b}	5.34^{b}	663^{b}	(After the 16 hours of heat ageing at 350°F. the samples turned brown and were too stiff to be tested.	
		3.0	1.2													
Silicone Emulsion 81432	8	10.0	3.1	5000	8600	98.7										
Catalyst Emulsion Tin Naphthenate		10.0	3.3	5000	7160	82.2	4.03^{c}	294^{c}	4.55^{c}	421^{c}	4.86^{c}	515^{c}	5.18^{c}	624^{c}	5.11^{c}	600^{c}
General Electric Company 12 min. at 302°F.		10.0	3.4													
Silicone Emulsion 81432	9	10.0	4.1	5000	8210^{a}	94.2^{a}	3.76^{b}	241^{b}	4.96^{b}	554^{b}	5.79^{b}	882^{b}	5.86^{b}	912^{b}	5.69^{b}	836^{b}
Catalyst Emulsion Tin Oleate		10.0	4.0													
General Electric Company 12 min. at 302°F.		10.0	4.3	5000	8500	97.5										

a Average of two samples tested
b Average of three samples tested
c Average of six samples tested
e With curing agent
f Without curing agent

TABLE IX (Cont'd.)

THE EFFECT OF ABRASION, TEMPERATURE AND AGEING AT 350°F. ON 8700 LB. DACRON WEBBING AFTER TREATMENT WITH VARIOUS RESIN FINISHES

Finishes Used	Group	Resin Bath Solids (%)	Dry Pickup (%)	Abrasion Cycles	Breaking Strength After Abrasion (lbs.)	Strength Retained % of Original	Flexibility Measurements: At Standard Conditions c	At Standard Conditions G	At -65°F c	At -65°F G	After Being Heat Aged at 350°F. For: 2 Hours c	2 Hours G	6 Hours c	6 Hours G	16 Hours c	16 Hours G
Silicone Emulsion 81432 General Electric Company) Catalyst Emulsion XEY-21 Dow Corning Corporation 12 Min. @ 302°F	10	10.0 10.0 10.0	2.8 3.2 3.2	5000 5000	8100 7400	92.9 84.9	3.30^b	160^b	3.88^b	261^b	4.66^b	451^b	4.96^b	544^b	4.76^b	481^b
Silicone Emulsion 81432 General Electric Company Catalyst Emulsion XEY-21 Dow Corning Corporation 12 Min. @ 302°F	11	10.0	1.7	5000	4860	55.8										
Silicone Emulsion 81432 Catalyst Emulsion Tin Oleate General Electric Company 12-15 Min. @ 302°F	12	10.0 12.0 12.0 20.0	3.6 4.2 4.3 8.2	5000 5000 5000 5000	7840 7160 7560 8000	90.0 82.2 86.7 91.8										
Silicone Emulsion 81432 Catalyst Emulsion Tin Naphthenate General Electric Company 12 Min. @ 302°F	13	10.0 20.0	3.8 8.4	5000 5000	4240 5000	48.6 57.4										
Silicone Emulsion 81432 Catalyst Emulsion Tin Oleate General Electric Company 12 Min. @ 302°F	14	10.0	3.9	5000	5300	60.8										
Silicone Emulsion 81432 Catalyst Emulsion Tin Oleate General Electric Company 12 Min. @ 302°F	15	10.0	3.5	5000	8040	92.3										

b Average of three samples tested

TABLE IX (Cont'd.)

THE EFFECT OF ABRASION, TEMPERATURE AND AGEING AT 350°F. ON 8700 LB. DACRON WEBBING AFTER TREATMENT WITH VARIOUS RESIN FINISHES

Finishes Used	Group	Resin Bath Solids (%)	Dry Pickup (%)	Abrasion Cycles	Breaking Strength After Abrasion (lbs.)	Strength Retained % of Original	Flexibility Measurements: At Standard Conditions c	At Standard Conditions G	At -65°F. c	At -65°F. G	After Being Heat Aged at 350°F. For: 2 Hours c	2 Hours G	6 Hours c	6 Hours G	16 Hours c	16 Hours G
Silicone Emulsion 81432	16	10.0	2.5	5000	5460	62.6										
Catalyst Emulsion Tin Naphthenate		10.0	2.2	5000	6500	75.3										
General Electric Company																
12 Min. @ 302°F																
Silicone Emulsion 112	17	5.0	1.9	5000	3700	99.8										
Catalyst Emulsion XEY-21		5.0	2.2	5000	8640	99.1										
Dow Corning Corporation		5.0	1.7				3.52[b]	193[b]	4.16[b]	319[b]	4.98[b]	543[b]	4.94[b]	534[b]	4.90[b]	521[b]
15 Min. @ 305°F																
Silicone Emulsion 108	18	5.0	1.7	5000	6140	70.4										
Catalyst Emulsion XEY-21																
Dow Corning Corporation																
15 Min. @ 305°F																
Silicone Emulsion 102	19	5.0	1.1	5000	4360	50.0										
Catalyst Emulsion XEY-21		10.0	2.5	5000	5660	64.9										
Dow Corning Corporation																
15 Min. @ 305°F																
Silicone Emulsion 105	20	8.0	3.5	5000	8520[a]	97.4[a]										
Catalyst Emulsion XEY-21		4.0	1.7	5000	8540[a]	98.0[a]										
Dow Corning Corporation		4.0	1.2				2.78[b]	95[b]	2.91[b]	109[b]	3.82[b]	246[b]	3.22[b]	148[b]	3.26[b]	153[b]
15 Min. @ 300°F																
Silicone Emulsion 104	21	5.0	1.9	5000	9120	104.6										
Catalyst Emulsion XEY-21		5.0	2.1	5000	8820	101.2										
Dow Corning Corporation		5.0	1.7				2.82[b]	100[b]	3.04[b]	125[b]	3.60[b]	208[b]	3.10[b]	133[b]	3.17[b]	142[b]
15 Min. @ 305°F																

a Average of two samples tested
b Average of three samples tested

The natural rubber latex BIND 404 (Group 4) at a rather low pickup afforded excellent abrasion resistance but the webbings turned stiff and brown after 2 hours at 350°F.

Webbing treated with either Hycar 1714 latex (Group 5) or Hycar 1572 latex (Group 6) was too stiff at -65°F. and after 2 hours at 350°F. Merlon BR (Group 7 - 1 to 3% pickup) afforded excellent abrasion protection but the treated webbing was too stiff at -65°F. and after 16 hours at 350°F. Flexibility after 6 hours at 350°F. was equivalent to that of the scoured and heat shrunk control. The question may arise as to the reason for evaluating Merlon BR here, since it was already being used at 5 to 8% pickup on nylon webbing and known to be too stiff at -65°F. It was thought that at the much lower pickup of 1 to 3% on Dacron webbing the flexibility might possibly be greater than in the case of the nylon webbing.

Efforts from this point on were directed toward the application and evaluation of silicone products. The results of these have been listed in Table IX, Groups 8 through 21.

Considering the data for Groups 8 through 16, which represent General Electric Silicones, it can be seen that some of these formulations afforded very good abrasion resistance. The flexibilities at standard conditions and at -65°F. for Groups 8, 9 and 10 were lower (stiffer) than that of the scoured control. In the case of Groups 8, and 9 at -65°F. the value of G, flexural rigidity, was 5 to over 6 times that of the control or, in other words, the webbings were that much stiffer at -65°F. than the control at -65°F. Silicone treated samples in Group 10 were only twice as stiff as the control at standard conditions and three times as stiff at -65°F. according to values of G. Heat aged samples in Group 10 were more flexible than the controls. Because of these results, this Group 10 formulation (General Electric Silicone emulsion and Dow Corning catalyst) was considered as a treatment which might possibly fulfill the requirements of the contract. However, experiments with other silicones showed that even better results could be obtained.

Groups 11 through 16 were various attempts to use other General Electric silicone emulsions and silicone catalyst emulsions. Emulsions used in Groups 11, 12, 13, 14 and 16 did not provide the necessary abrasion resistance and for this reason work with them was discontinued. Group 15 did have the necessary abrasion resistance but other silicone treatments gave even better resistance.

Silicone emulsions mentioned in Groups 17 through 21 were provided by the Dow Corning Corporation. Here again some of the emulsions that were applied were found to be unsatisfactory from the standpoint of required abrasion resistance and work with these was terminated. These include those used in Groups 18 and 19. Groups 17, 20 and 21 showed considerable promise and testing of these was carried through the 16 hour heat ageing test at 350°F.

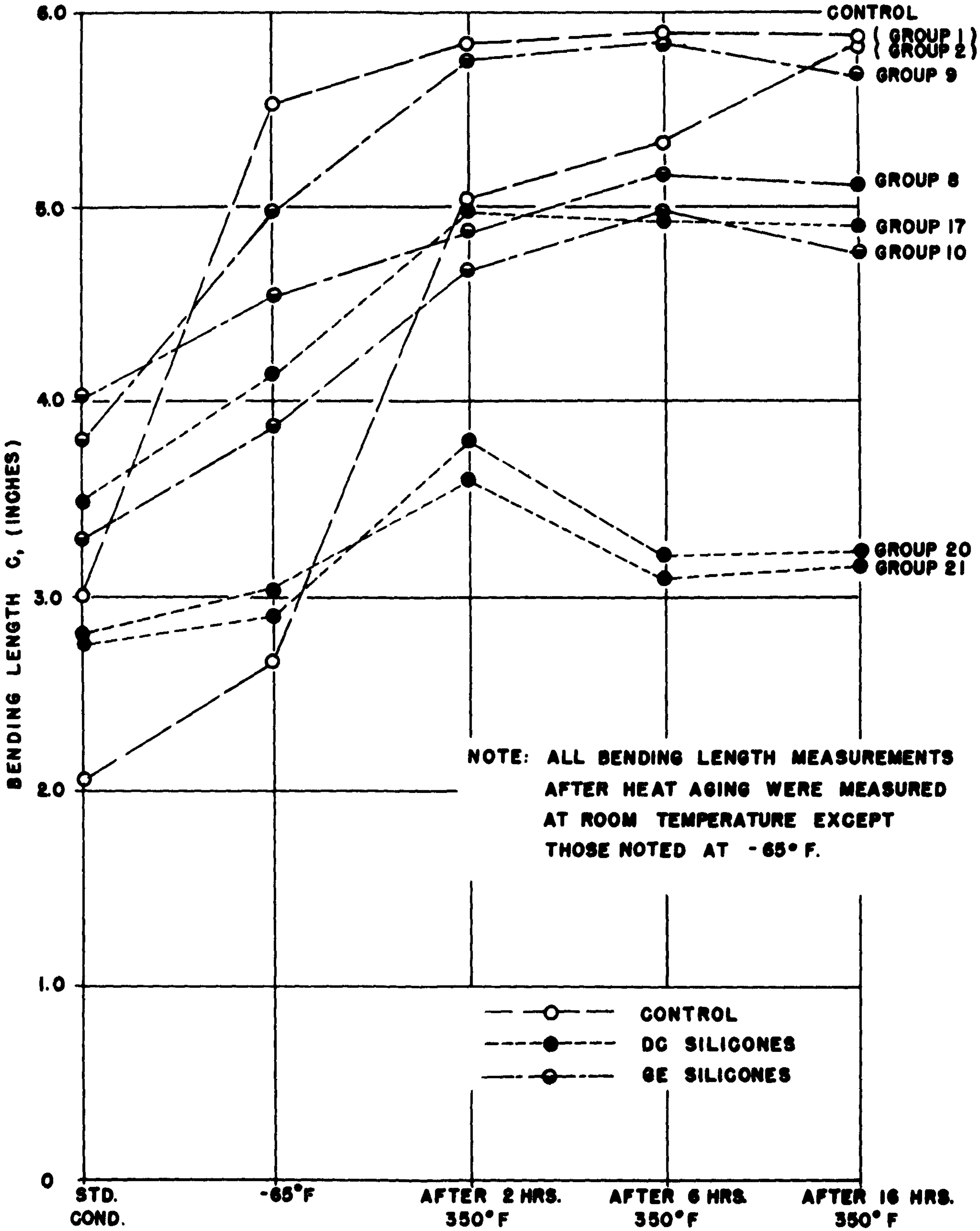


FIGURE 4. THE EFFECT OF TEMPERATURE AND AGING AT 350°F ON THE BENDING LENGTH OF 8700 LBS. DACRON WEBBING, TREATED WITH VARIOUS SILICONE FINISHES.

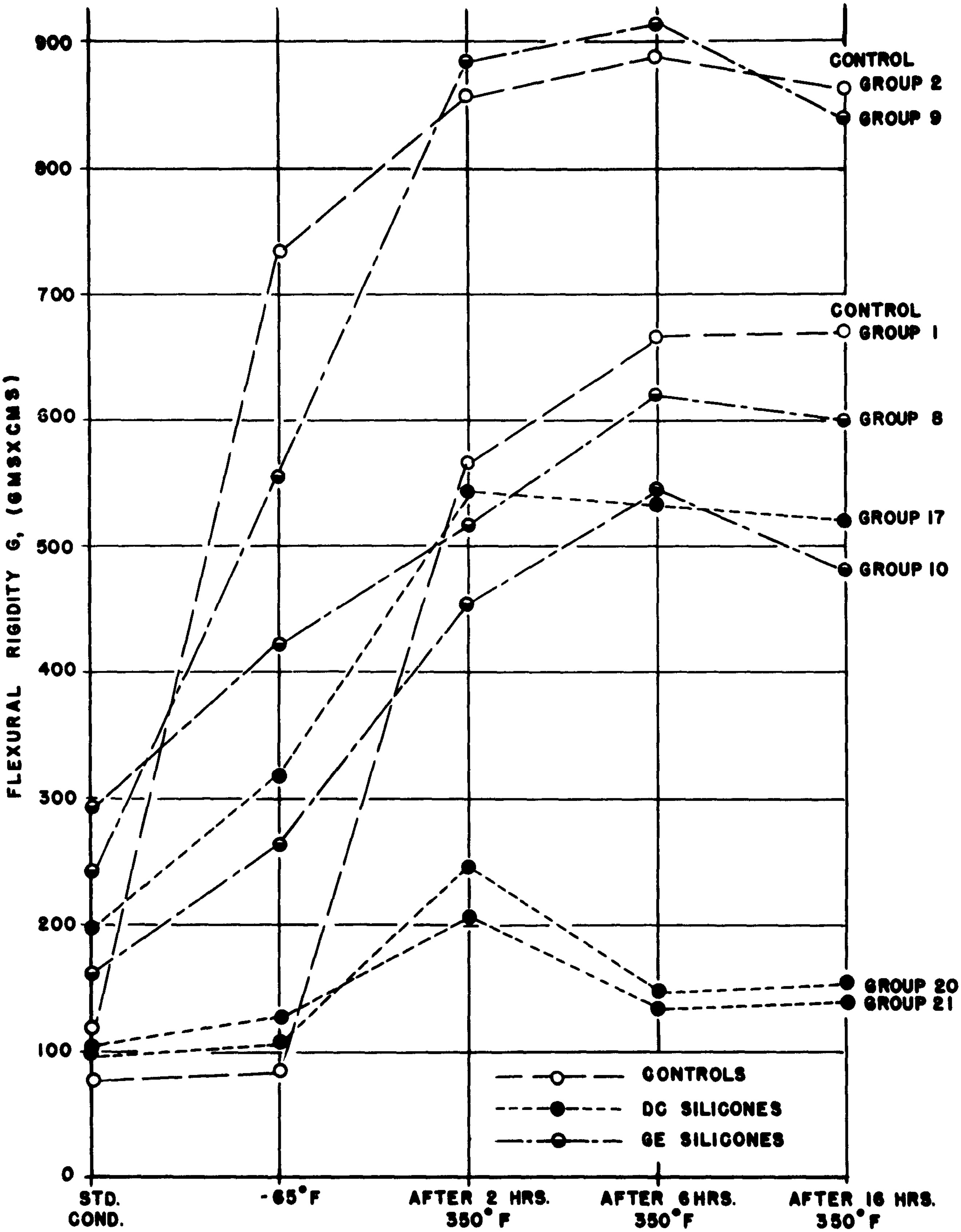


FIGURE 5. THE EFFECT OF TEMPERATURE AND AGING AT 350° F ON THE FLEXURAL RIGIDITY OF 8700 LB. DACRON WEBBING, TREATED WITH VARIOUS SILICONE FINISHES.

A relative comparison of the bending length and flexural rigidity of these silicone treated webbings which showed good abrasion resistance is shown in Figures 4 and 5. Using the scoured control samples as the criteria for flexibility, it can be seen from these data that the silicone emulsions and catalysts used in Groups 20 and 21 provided the greatest advantage both in abrasion resistance and flexibility when compared with any of the other groups. Both silicones DC 104 and DC 105 behaved similarly, but DC 104 provided slightly greater flexibility after heat ageing at 350°F. for 2, 6 and 16 hours. For this reason the DC 104 treatment with catalyst XET 21 was chosen to be more thoroughly evaluated with respect to heat ageing and resistance to artificial sunlight.

VIII. FURTHER EVALUATION OF SILICONE TREATMENT DC 104 XEY 21:

8.1 Tests

Having selected Dow Corning's silicone emulsion DC 104 and catalyst XEY 21 as the most promising treatment thus far with respect to flexibility at standard conditions, -65°F. and after heat ageing, more treated samples were prepared for determination of the effect of heat ageing on tensile strength and abrasion resistance. Also, ageing tests for 100 hours under artificial sunlight remained to be carried out.

8.2 Discussion of Data

The data in Table X indicated that the treated webbing satisfactorily withstood 6 hours heat ageing at 350°F. The results of 16 hour heat ageing tests were questionable and inconsistent. In the case of continuous 16 hour ageing at 350°F., the samples which were subsequently abraded had greater breaking strength than those not abraded. What appeared to be another discrepancy was that samples which had been cyclically exposed to heat ageing at 350°F. (in increments of two hours) had higher breaking strength, whether or not they were abraded, than the samples exposed continuously for 16 hours at 350°F. In addition to these inconsistent results there was an indication, based on one accurate breaking strength measurement that some damage had occurred to the samples after they had been treated with DC 104 and catalyst XEY 21 and exposed for 100 hours in the "Weatherometer". The exposed treated sample retained only 69% of the strength of the exposed untreated webbing. The overall results from the particular group of tests were actually considered inconclusive because of the slippage that occurred during the testing of four of the five samples for breaking strength. The slippage of the samples between the capstan jaws of the Tinius Olsen Tensile Tester prevented the determination of accurate strength measurements. However, despite the inconclusiveness of these tests the indication that the webbing samples might have been weakened during their exposure in the "Weatherometer" was completely unexpected. To date the silicones and catalysts that were used in these tests have not been known to seriously injure or degrade fabrics or fibers to which they have been applied. They do not absorb ultraviolet light and they do not accelerate fading of dyes on fabrics. However, the untreated Dacron webbing

TABLE X

THE EFFECT OF ABRASION, TEMPERATURE, AGEING AT 350°F, AND 100 "WEATHEROMETER" HOURS ON SILICONE TREATED 8700 LB. DACRON WEBBING

Finish Used	Resin Bath Solids (%)	Wet Pickup (%)	Dry Pickup (%)	Ageing	Abrasion Strokes	Breaking Strength After Abrasion (lbs.)	Strength Retained % of Original	Bending Length (c) and Flexural Rigidity (G) Values of Webbing: At Standard Conditions c	At Standard Conditions G	-65°F c	-65°F G	After Being Heat Aged at 350°F. For: 2 Hours c	2 Hours G	6 Hours c	6 Hours G	16 Hours c	16 Hours G	6 Hours (2 Hr.Cycles) c	6 Hours (2 Hr.Cycles) G	16 Hours (2 Hr.Cycles) c	16 Hours (2 Hr.Cycles) G
Controls - Scoured and heat shrunk @ 350°F					None	8715[a]		2.1[c]	76	2.7[c]	85	5.1[c]	565	5.3[c]	663	5.9[c]	670				
				(100 hours)	None	7880)	90.4)	2.8[b]	92					5.8[b]	862						
				(artificial)	None	7880) Av.	90.4) Av.	2.5[b]	69							5.7[b]	828				
				(sunlight)	None	8260) 7968	94.8) 91.4														
				( )	None	7960)	91.3)														
				( )	None	7860)	90.2)														
				None	5000																
Silicone Emulsion DC104	5.0	--	1.9	None	5000	3918[d]	44.9														
& Catalyst XEY21 - Dow	5.0	--	2.1	None	5000	9120	104.6														
Corning Corporation	5.0	31	1.7	(As noted)		8820	101.2														
15 Min. @ 305°F	5.0	29	1.7	(under Flex-)																	
	5.0	31	1.7	(ibility)				2.5[b]	73	2.9[b]	114	4.1[b]	314								
	5.0	31	1.7	(Measurements)										3.8[b]	250						
	5.0	33	1.7	( )												4.3[b]	369				
"	5.0	31	1.8	(2 Hours @)	5000													3.6[b]	214	3.1[b]	134
	5.0	31	1.8	(350°F)	5000	7960)	91.3)														
	5.0	33	2.0	( )	5000	7520) Av.	86.3) Av.														
	5.0	32	1.9	( )	None	7900) 7793	90.6) 89.3														
	5.0	32	1.8	( )	None	8480) Av.	97.3) Av.														
	5.0	31	1.8	( )	None	8880)	101.9)														
						8840) 8733	101.4) 100.2														
"	5.0	31	1.8	(6 Hours @)	5000																
	5.0	32	1.8	(350°F)	5000	7840)	90.0)														
	5.0	35	2.1	( )	5000	7620) Av.	87.4) Av.														
	5.0	31	1.8	( )	None	7800) 7753	89.5) 89.0														
	5.0	31	1.8	( )	None	8380) Av.	96.2) Av.														
	5.0	33	1.9	( )	None	8120)	93.2)														
						8440) 8313	96.8) 95.4														

a Average of two tests
b Average of three tests
c Average of six tests
d Average of eight tests

TABLE X (Cont'd.)

THE EFFECT OF ABRASION, TEMPERATURE, AGEING AT 350°F, AND 100 "WEATHEROMETER" HOURS ON SILICONE TREATED 8700 LB. DACRON WEBBING

Finish Used	Resin Bath Solids (%)	Wet Pickup (%)	Dry Pickup (%)	Ageing	Abrasion Strokes	Breaking Strength After Abrasion (lbs.)	Strength Retained % of Original	
Silicone Emulsion DC104	5.0	33	1.9	(16 Hours)	5000	6380) Av.	73.2) Av.	)
Catalyst XEY21	5.0	33	2.1	(@ 350°F)	5000	5900) 5820	67.7) 66.8	)
Dow Corning Corporation	5.0	34	2.0	( )	5000	5180)	59.4)	)Questionable
15 Min. @ 305°F	5.0	33	1.9	( )	None	5020) Av.	57.6) Av.	) Data
	5.0	33	1.9	( )	None	4720) 5213	54.2) 59.8	)
	5.0	36	2.0	( )	None	5900)	67.7)	)
"	5.0	37	2.3	(6 Hours @)	5000	7940) Av.	91.1) Av.	
	5.0	32	1.9	(350°F -)	5000	7740) 7786	88.8) 89.3	
	5.0	37	2.0	(2 Hour)	5000	7680)	88.1)	
	5.0	29	1.6	(Cycles)	None	8060)	92.5)	
	5.0	28	1.6	( )	None	8200) Av.	94.1) Av.	
	5.0	33	1.8	( )	None	8120) 8126	93.2) 93.3	
"	5.0	32	1.8	(16 Hours @)	5000	5820)	66.8)	)
	5.0	33	1.8	(350°F -)	5000	6480) Av.	74.4) Av.	)
	5.0	30	1.8	(2 Hour)	5000	6480) 6260	74.4) 71.9	)Questionable
	5.0	34	1.9	(Cycles)	None	6260)	71.8)	) Data
	5.0	28	1.6	( )	None	6680) Av.	76.6) Av.	)
	5.0	37	2.1	( )	None	6040) 6326	69.3) 72.6	)
"	5.0	35	2.1	(100 Hours)	None	5300)		
	5.0	36	2.0	(artificial)	None	5740) Jaw		
	5.0	35	1.9	(sunlight)	None	5140) Slippage		
	5.0	31	1.7	( )	None	5580)		
	5.0	33	1.8	( )	None	5840	69.0	(Based on exposed untreated webbing)

retained 91.4% of the original strength after 100 hours exposure while the silicone treated sample appeared to retain in the order of magnitude of 70% of the untreated exposed. This pointed to the silicone coating as the source of the trouble.

The first attempt to answer this question of loss in tensile strength as a result of "weatherometer" tests was made through conversations with qualified Dow Corning personnel of Midland, Michigan. Here it was learned that little was known of the action of artificial sunlight on Dacron that had been treated with this silicone resin and catalyst. There appeared to be no reason for or explanation of the degradation under these conditions. It was apparent that additional experiments would be necessary in order to attempt to clarify the "questionable" data.

8.3 Tests on One Inch, 3400 lb. Silicone Treated Webbing

Based upon ease of testing, a 1 inch, 3400 lb. heat stable Dacron webbing developed under Contract AF 33(600)-24087 and made to meet as closely as possible Specification MIL-W-4088 for nylon webbing (See Technical Report 55-135, Table V, Page 7) was substituted for the 8700 lb. webbing. Since this webbing was identical in construction to the 8700 lb. type, it was felt that the results of tests on this webbing would be directly applicable.

The one inch, 3400 lb. strength webbing was scoured, as previously described, with Triton X-100 in order to remove the producer's yarn finish. Subsequent treatments were selected so that the effect of each component of this silicone finish could be determined. Concentrations of the DC 104 silicone alone, of each catalyst alone, or of combinations were identical with those used in the standard formula as applied to the 8700 lb. webbing. Thus the following experiments were conducted on the 3400 lb. webbing:

1. DC 104 alone
2. Catalyst XEY 21 alone
3. DC 104 plus catalyst XEY 21
4. DC 104 plus General Electric Catalyst

The amount of General Electric Catalyst used was 4% based on the weight of silicone solids in the pad bath. The treated samples were then exposed to the continuous heat ageing test for 16 hours at 350°F., and the 100 hours "weatherometer" exposure test. These conditions were chosen because it was here that discrepancies appeared when the 8700 lb. webbing was tested.

8.4 Results of Tests on One Inch, 3400 lb. Webbing

The results of these experiments are listed in Table XI and may be summarized as follows:

TABLE XI

THE EFFECT OF AGEING 16 HOURS AT 350°F AND
OF 100 "WEATHEROMETER" HOURS ON SILICONE TREATED
1 INCH 3400 LB. DACRON WEBBING

				Unexposed		Ageing Tests					
						After Heat Ageing 16 Hours @ 350°F			After 100 Hours Artificial Sunlight		
							% Strength Retained			% Strength Retained	
Finish Used	Resin Bath Solids (%)	Wet Pickup (%)	Dry Pickup (%)	Breaking Strength (lbs.)	% of Control Br. Strength	Breaking Strength (lbs.)	Based on Exposed Control	Based on Unexposed Treat.Sample	Breaking Strength (lbs.)	Based on Exposed Control	Based on Unexposed Treat.Sample
Control - Scoured				3400)		3200)			3050)		
				3325)Av.		3175)Av.			3050)Av.		
				3450)3415		3150)3155		92.4	2950)3020		88.4
				3450)		3150)			3000)		
				3450)		3100)			3050)		
DC-104 Silicone Emulsion & Catalyst XEY-21 15 Min. @ 305°F	4	42	2.0	2625 J.B.							
	4	42	1.9	2650 J.S.							
	4	41	1.9	2500 J.S.							
	4	44	1.8	2100 J.S.							
	4	44	2.0	1750 J.B.							
	4	43	1.8						1900)		
	4	42	1.9						1850)Av.		
	4	41	2.0						1900)1885	62.4	55.0
	4	43	2.0						1875)		
	4	46	1.7						1900)		
	4	41	1.7			3175)Av.	100.6				
	4	43	1.7			3175)3175					
	4	44	1.7			2825 J.B.					
	4	45	1.7			2425 J.S.					
	4	45	1.7			2550 J.B.					
Catalyst XEY-21 (alone) 15 Min. @ 305°F	0.4	46	0.12	3000 J.B.							
	0.4	44	0.17	3400)							
	0.4	44	0.17	3450)Av.	99.6						
	0.4	47	0.07	3375)3400							
	0.4	46	0.14	3375)							
	0.4	45	0.12						2800)		
	0.4	45	0.10						2900)Av.		
	0.4	47	0.05						2900)2900	96.0	85.3
	0.4	45	0.10						3000)		
	0.4	46	0.19						2900)		
	0.4	47	0.07			3050)					
	0.4	46	0.17			3100)Av.					
	0.4	46	0.15			3000)3075	97.5	90.4			
	0.4	45	0.12			3125)					
	0.4	46	0.09			3100)					

J.B. = Jaw Break
J.S. = Jaw Slippage

TABLE XI (Cont'd.)

THE EFFECT OF AGEING 16 HOURS AT 350°F AND
OF 100 "WEATHEROMETER" HOURS ON SILICONE TREATED
1 INCH 3400 LB. DACRON WEBBING

Finish Used	Resin Bath Solids (%)	Wet Pickup (%)	Dry Pickup (%)	Unexposed: Breaking Strength (lbs.)	Unexposed: % of Control Br. Strength	After Heat Ageing 16 Hours @ 350°F: Breaking Strength (lbs.)	After Heat Ageing: % Strength Retained, Based on Exposed Control	After Heat Ageing: % Strength Retained, Based on Unexposed Treat. Sample	After 100 Hours Artificial Sunlight: Breaking Strength (lbs.)	After Sunlight: % Strength Retained, Based on Exposed Control	After Sunlight: % Strength Retained, Based on Unexposed Treat. Sample
DC104 Silicone Emulsion	4	43	1.7	3350	98.1						
(No Catalyst)	4	42	1.7	3300 J.B.							
15 Min. @ 305°F	4	44	1.8	3100 J.S.							
	4	44	1.7	2900 J.B.							
	4	45	1.9	2900 J.B.							
	4	42	1.7						2050		
	4	43	1.8						2075 J.B.	66.2	59.7
	4	43	1.8						2050)Av.		
	4	44	1.7						1950)2000		
	4	45	1.8						2000)		
	4	45	1.8			2550	80.8	76.1			
	4	42	1.8			2150 J.B.					
	4	42	1.8			2200 J.B.					
	4	44	1.8			2000 J.B.					
	4	44	1.9			2150 J.B.					
DC104 Silicone Emulsion &	4	42	2.0	2650 J.B.							
G. E. Catalyst	4	44	2.0	2650 J.B.							
15 Min. @ 305°F	4	43	2.0	3250	95.2						
	4	42	2.0	2900 J.B.							
	4	42	2.0						2250)		
	4	41	2.1						2250)Av.		
	4	42	1.9						2200)2250	74.5	69.2
	4	42	1.8						2300)		
	4	41	1.9			2400 J.B.					
	4	43	1.9			2425 J.B.					
	4	42	2.0			2200	101.4	98.5			
	4	42	2.0			2000 J.B.					

J.B. = Jaw Break
J.S. = Jaw Slippage

The tensile strength of samples treated with DC 104 and catalyst XEY 21 was practically unaffected by the heat ageing test at 350°F. for 16 hours. However, samples with this finish did lose 40-45% of their tensile strengths after being exposed for 100 hours in the "weatherometer".

The tensile strength of samples treated with catalyst XEY 21 alone showed no evidence of being affected either by heat ageing tests or after exposure for 100 hours in the "weatherometer".

The samples treated with DC 104 alone showed a 20-25% loss in breaking strength after the heat ageing test and a loss of 35 to 40% in tensile strength after 100 hours exposure in the "weatherometer".

The tensile strength of samples treated with DC 104 and General Electric silicone catalyst 385-71-594 showed no evidence of being affected by heat ageing tests. However, the samples did show a loss in tensile strength of 25-30% after being exposed to 100 hours in the "weatherometer".

8.5 Discussion of Results of Tests on One Inch Webbing

It is therefore quite apparent as a result of these tests that:

a. When DC 104 is applied to Dacron and cured with either the XEY 21 or the General Electric catalyst, the tensile strength of the webbing is practically unaffected after being exposed to continuous heat ageing at 350°F. for 16 hours.

b. When the Dacron webbing is treated with DC 104 alone or in combination with either catalyst, XEY 21 or General Electric 385-71-594, there is a loss of 30-45% in tensile strength after 100 hours of exposure in the "weatherometer".

The DC 104 emulsion when applied alone and not subsequently polymerized causes an apparent strength loss on heat ageing for 16 hours at 350°F. This loss is avoided when a catalyst is employed (the normal situation). Thus the presence of unpolymerized silicone might be the cause of Dacron's strength loss.

By the same token, it may be hypothesized that a similar mechanism could occur under artificial sunlight. Here both the DC 104 alone (i.e., unpolymerized) as well as the DC 104 plus catalyst (essentially polymerized) show similar strength losses after 100 hours "weatherometer" exposure. (See Table XI). The use of DC 104 with catalyst does not necessarily result in 100% polymerization. Probably a small but significant amount of unpolymerized silicone is present which again may have an action on the Dacron. Strictly as an hypothesis it is suggested that the "weatherometer" action may cause depolymerizations with resulting increase in unpolymerized silicone content and attendant strength loss in the Dacron.

IX. SELECTION OF OPTIMUM RESIN FINISH:

A final requirement of this program was the application of the optimum finish to 250 yards of the 8700 lb. strength Dacron webbing for delivery to, and evaluation by Wright Air Development Center.

From the foregoing discussion it becomes apparent that the DC 104 silicone formulation meets the greatest number of specification requirements, namely, abrasion resistance, thickness, weight, extractibles, and flexibility at room temperature, at -65°F., and after heat ageing. It apparently fails to meet the "weatherometer" test in that the strength retention after 100 exposure hours is 65 to 75% as compared with the 90% requirement.

At the current writing no resin finish is known which will meet all requirements. Indeed, in spite of its failure to meet the "weatherometer" test, this silicone finish is far superior to all other materials investigated.

At a conference among Wright Air Development Center and Fabric Research Laboratories, Inc., representatives it was agreed to proceed with applying the DC 104 formulation to the 250 yards of webbing. Details of this semi-commercial application follow.

9.1 Scouring Procedure

About 325 yards of the 8700 lb. Dacron webbing as received from Murdock Webbing Company, were scoured in a dyebeck. This length of webbing, after shrinkage, gave the required 250 yards of material. The ends of the webbing were tied together around the dyebeck reel so that the webbing was continuously rotated from the front to the back of the unit during the scour. The webbing was in a loose condition with a minimum of tension throughout the procedure. The scouring bath contained 3 grams of Triton X-100 per liter of solution, and the bath ratio was 10 to 1.

The bath temperature was raised slowly as the webbing was rotated in the unit until it reached 203-205°F. in the center of the unit. However, since the bath was heated by bubbling live steam into it at the front of the unit, the temperature of the scour actually varied between 203°F. and 212°F. In order to insure thorough scouring, the webbing was circulated for 20 minutes under these conditions. Cold water was then added until the temperature dropped to 110°F., when the entire scouring bath was dropped. Several hot water rinses followed at 140-160°F. and several more at 100-110°F. to insure complete removal of the Triton X-100. Most of the water was then squeezed out of the webbing by running it through a three roll padder with a pressure of 2 to 3 tons. The webbing was then allowed to air dry before being heat shrunk. The use of a dyebeck for scouring the webbing should not be interpreted as a recommendation that it be done this way commercially. It happened to be a convenient available piece of equipment. During this operation the webbing was guided by hand to avoid entanglement.

9.2 Heat Shrinkage

The Dacron webbing was processed with a minimum amount of tension through a Morrison "heat setting" unit at Cheney Brothers Company, Manchester, Connecticut. Due to the damp condition of the webbing, it was necessary to pass it through the unit four times to insure dryness and proper shrinkage, thus making it stable to shrinkage up to 350°F. The following table shows the number of passes made and the temperature and speeds used. The first three runs were used to completely dry the webbing and the last run was the one that actually provided the heat shrinking and stabilizing action.

Run	Temperature	Yards/Minute	Contact Time
1	250°F. ± 2°F.	7	55 seconds
2	300°F. ± 2°F.	10	39 seconds
3	300°F. ± 2°F.	12	32 seconds
4	385°F. ± 2°F.	7	55 seconds

9.3 Application of the Silicone Emulsion

The padding and curing of the 250 yards of Dacron webbing was performed at the Murdock Webbing Company, Pawtucket, Rhode Island. The resin bath was made up to contain 6.3% resin solids, using Dow Corning's 104 silicone emulsion. The catalyst XEY 21 was added to the concentrated silicone emulsion in an amount that equalled one part catalyst emulsion for every five parts of silicone emulsion. The entire emulsion was then diluted with the addition of water to the required volume to give 6.3% resin solids in the bath. The webbing was then passed through the resin bath and between two rubber rolls without the use of pressure.

This formulation and procedure yielded a wet pickup of approximately 33%. The theoretical dry pickup was calculated to be 2.1%. The actual dry pickup, which was determined by the difference in weights of a sample of webbing before and after padding and curing, was 2.2%.

9.4 Curing of Silicone Treated Webbing

After padding with the silicone emulsion, the webbing was put directly through two ovens which were arranged in tandem. Each oven was regulated to allow the passage of webbing through it with the minimum amount of tension and at a temperature of 305°F. The webbing remained in each oven for a period of 7.5 to 8 minutes making the length of time at which the webbing was exposed to a temperature of 305°F. a total of 15 to 16 minutes. Although the temperature of the ovens was controlled by a thermostat it was reported that the temperature in the second oven was in excess of the set temperature of 305°F. by 30 to 35°F. The temperature used certainly met the minimum temperature requirements for the complete curing of the silicone resin.

9.5 General Comments

Thickness of the treated webbing was 0.0303 inch, that of the untreated was .0319 inch. These were the averages of 20 measurements.

Attention should be called to the slipperiness of the treated webbing which caused a number of jaw slippage during the breaking strength tests. The slipperiness may adversely affect the efficiency of sewn joints or snubbers used with this webbing.

Total yardage of the treated webbing was found to be 258 3/4. Of this, 250 3/4 yards were shipped to Wright Air De.elopment Center on July 12, and the remaining 8 yards were kept at these laboratories for further testing.